WTNP128 – Test of splitting per corner of the concrete under fluid pressure

Abstract:

The test presented here makes it possible to check the good performance of the elements of joints with hydraulic coupling and use of the cohesive models.

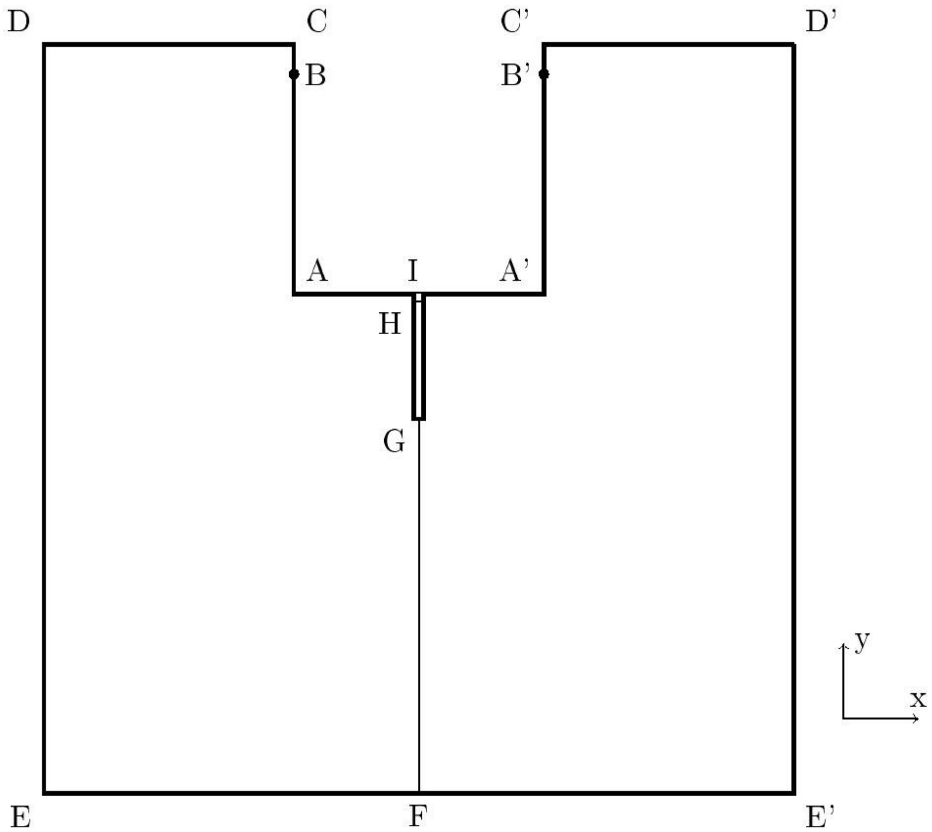
The modelled test is a test of splitting per corner with fluid pressure in crack.
One has for this test comparisons with experimental and numerical tests.

1 Problem of reference

the test of splitting ("wedge splitting test") was proposed initially by Brühwiler and Wittmann[bw] in order to obtain a stable crack propagation and thus to determine the properties of fracture of the concrete. Slowik and Saouma[ss] then used this test in order to study the effect of a fluid pressure in crack. Segura and Carol[sc] modelled this test of splitting under fluid pressure. One takes again here the test carried out by Slowik and Saouma.

A device, known as of "corner", allows to apply a force to the points B and B' (see figure 1.1-a) in order to separate the sample into two. The experiment is controlled by the CMOD (Ace Mouth Opening Displacement), i.e. imposed displacement enters B and B'.

1.1 Geometry



Appears 1.1-a: Geometry of the sample

Coordinated of the points (in mm):

	x	y		x	y
A	-50	51	A'	50	51.-50 .138
B			B'	50. 138 .-50	
C		150	C'	50. 150	
D	-150	150.	D'		

		150. 150			
E	-150	-150	E'	150	-150
F	0	-150	G	0	0
H	0	50	I	0	51

the sample has one thickness of $100\,mm$.

1.2 Properties of the material

- Properties of the interstitial fluid (liquid water):

Density	$1.10^{-6}\,kg.mm^{-3}$
Viscosity	$1.10^{-9}\,MPa.s$

One considers that water is incompressible.

- Properties of the solid mass:

The concrete block is elastic and has the following properties:

Young modulus	$27500\,MPa$
Poisson's ratio	$0{,}2$

being given the scales of time considered and the permeability of crack very high comparatively, the concrete is supposed to be impermeable. It is thus modelled by elements D_PLAN classics.

- Properties of discontinuity:

Discontinuity is broken up into three parts:

- The rubber membrane which ensures the sealing of the notch;
- The notch in which one imposes a constant pressure;
- The path of cracking the length whose the crack is propagated.

The membrane has a linear elastic behavior. One uses constitutive law JOINT_BANDIS with the parameter $\gamma=0$ in order to make it linear. The properties of the membrane are the following ones:

Initial normal stiffness K_{ni}	$20\,MPa.mm^{-1}$
Coefficient γ	0

For the notch, one uses model CZM_LIN_REG by initializing the local variables so as to have initially broken elements.

For crack, one uses model CZM_EXP_REG with the following parameters:

Energy of Forced G_c	$0{,}150\,MPa.mm$
cracking critical σ_c	$3{,}25\,MPa$

the numerical parameters of the elements of joints with cohesive model are

PENA_ADHERENCE	1.10^{-3}
PENA_CONTACT	1

•Properties of the point of crack

Modulates of Biot N	$0{,}3.10^{-3}\,MPa.mm^{-1}$
fictitious Opening OUV_FICT	10 mm

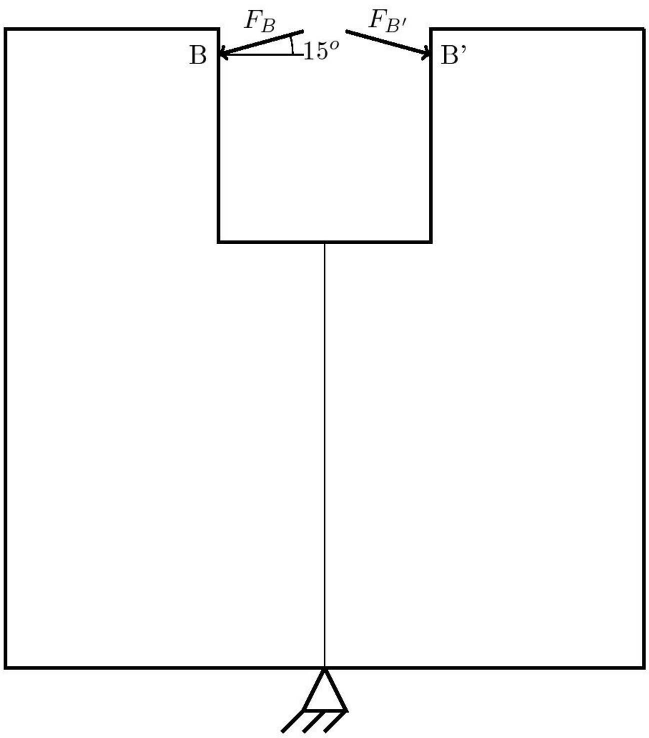
1.3 Initial conditions

the fluid pressure is initially of $0{,}21\,MPa$ in the notch and $0{,}0\,MPa$ future crack.

1.4 Boundary conditions

the mechanical and hydraulic boundary conditions are the following ones:

- In F : displacements blocked in all the direction and pressure null imposed;
- In the notch $[GH]$: pressure imposed of $0{,}21\,MPa$;
- In the membrane $[HI]$: pressure imposed of $0{,}0\,MPa$;
- In B and B', displacements are symmetric;
- In B', one imposes a force in the direction $\begin{pmatrix}\cos(\alpha)\\-\sin(\alpha)\end{pmatrix}$, whose intensity is controlled by the component DX of displacement at the point B'. At every moment t, the horizontal component of displacement must B' about it be equal to $u_x=-\frac{q}{2}t$, where q is the rate loading. One thus uses control with option DDL_IMPO.



In addition, the solid mass being impermeable one blocks the exchanges of fluid between crack and solid mass. The fluid pressures on edges of the element of joint and the hydraulic Lagrange multipliers are blocked to zero.

2 Reference solution

the reference solution is resulting from the experimental results of Slowik and Saouma [2]

2.1 Bibliography

1.Brühwiler, E., Witmann, F.H., The wedge splitting test, has new method of performing stable fracture mechanics tests, *Engineering Fractures Mechanics*, 1990,35,1/2/3,117-125

2.Slowik, V., Saouma, V.E., Toilets Presses in Propagating Concrete Aces, *Newspaper of Structural Engineering*, 2000,126,2,235-242

3.Segura, J. Mr., Carol, I., Numerical Modelling of pressurized fracture evolution in concrete using zero-thickness interface elements, *Engineering Fractures Mechanics*, 2010,77,9,1386-1399

3 Modelization A

3.1 Characteristic of the modelization To

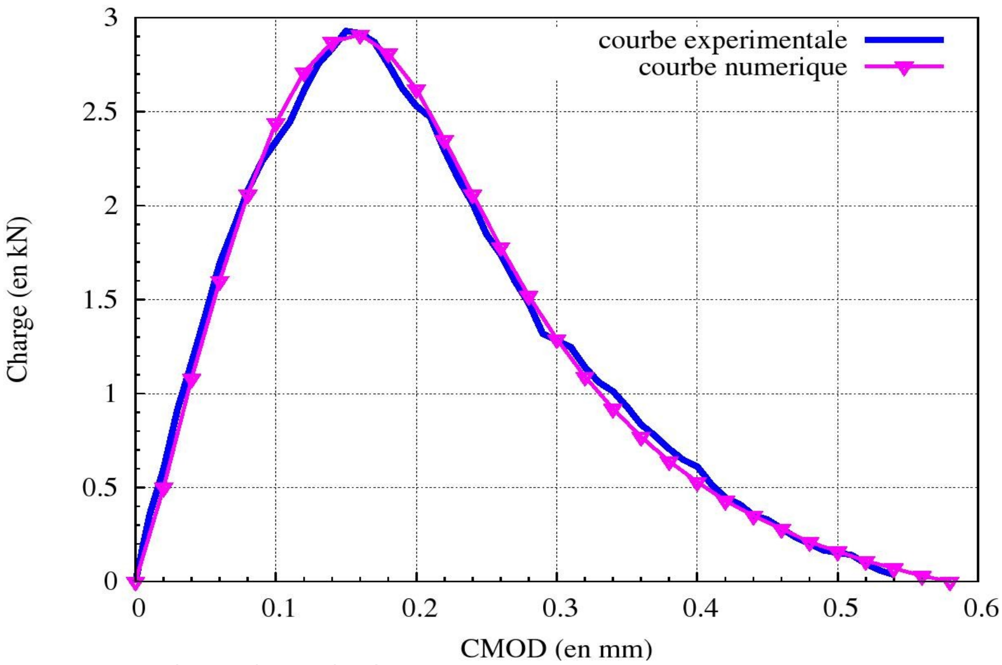
the modelization is carried out in plane strains with 3644 elements `TRI3` for the solid mass and 201 elements `QU4` for discontinuity. The cohesive model adoptee is `CZM_EXP_REG`. The mechanical loading is slow: the rate loading q_t is of $0{,}002\,\mu m.s^{-1}$.

Discretization in time: 29 time step of $10\,s$.

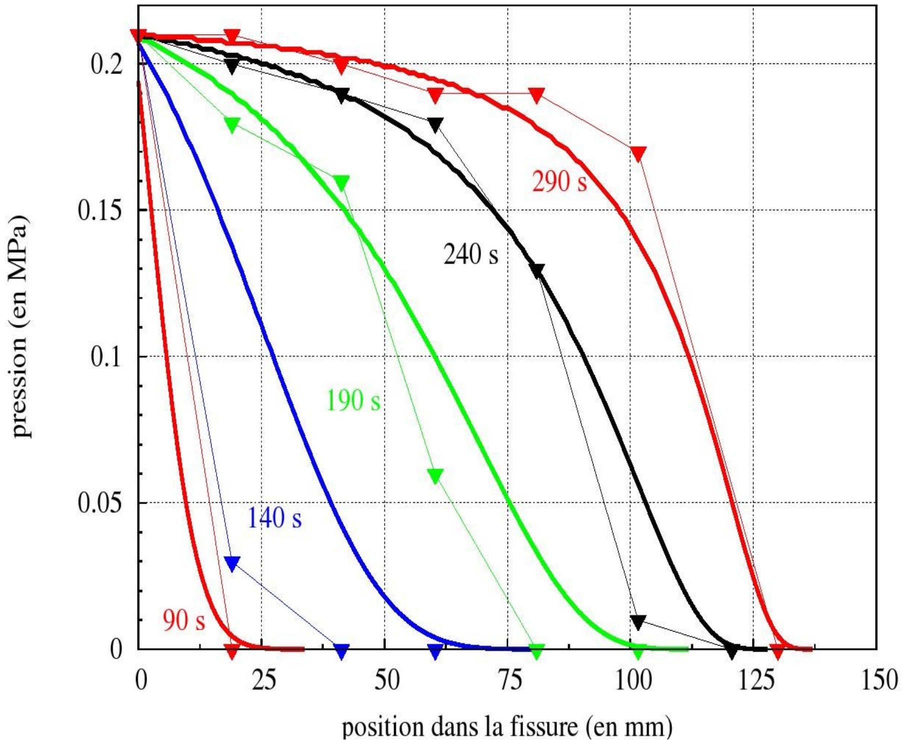
3.2 Quantities tested and results

One compares the results of the numerical modelization with those obtained in experiments by Slowik and Saouma[ss].

The figure 3.2-a watch the applied force by the corner according to the CMOD and the figure 3.2-b gives the profiles of pressure in crack.



Appear 3.2-a: Curve force-CMOD obtained numerically and comparison with the experimental results of Slowik and Saouma



Appear 3.2-b: Profiles of pressure in crack at various times. The numerical curves are the thick curves. Experimental measurements (Slowik and Saouma) are illustrated by the full triangles.

The curve force-CMOD obtained numerically is very close to the experimental curve. Moreover, the tendencies of evolution of the pressure in crack are also well reproduced.

It is also noted that these results are very similar to those obtained numerically by Segura and Carol[sc].

One carries out a test of comparison with the experiment on the component according to x applied force in B' (option FORC_NODA) like on the pressure in a point of crack.

Not	Time (s)	Fx (kN/mm^2) reference	Fx (kN/mm^2) Aster	Difference (%)
B'	100	-12,65	-13,08	3,4.150
B'		-6,41	-6,46	0,76
B'	250	-0,765	-0,792	3,5

X (mm)	Y (mm)	Times (s)	$PRE1$ (Mpa) reference	$PRE1$ (MPa) Aster	Difference (%)
0.-41.140			0,155	0,149	3,8
0.-41.190			0,190	0,188	0,86
0.-41.240			0,200	0,202	0,81

One adds the test of NON-regression following:

X (mm)	Y (mm)	Times (s)	$PRE1$ (Mpa) **Aster**
0.-41.140			0,1491
0.-41.190			0,1884
0.-41.240			0,2016

4 Modelization B

4.1 Characteristic of the modelization

the characteristics of the modelization B are identical to those of the modelization A , excluded:

- rate loading, which is 100 times higher: q_t is equal to $0{,}2\,\mu m.s^{-1}$.
- materials parameters following

the Modulus Young	$39000\,MPa$
Energy of Forced G_c	$0{,}178\,MPa.mm$
cracking critical σ_c	$3{,}30\,MPa$
Modulus of Biot of the cohesive zone N	$0{,}5.10^{-3}\,MPa.mm^{-1}$

Discretization in time: 42 time step of $0{,}1\,s$.

4.2 Quantities tested and results

the figure 4.2-a watch the applied force by the corner according to the CMOD.

The figure 4.2-b gives the profiles of pressure along crack. In accordance with what is expected and the loading being faster, the fluid front was propagated less far with CMOD given.

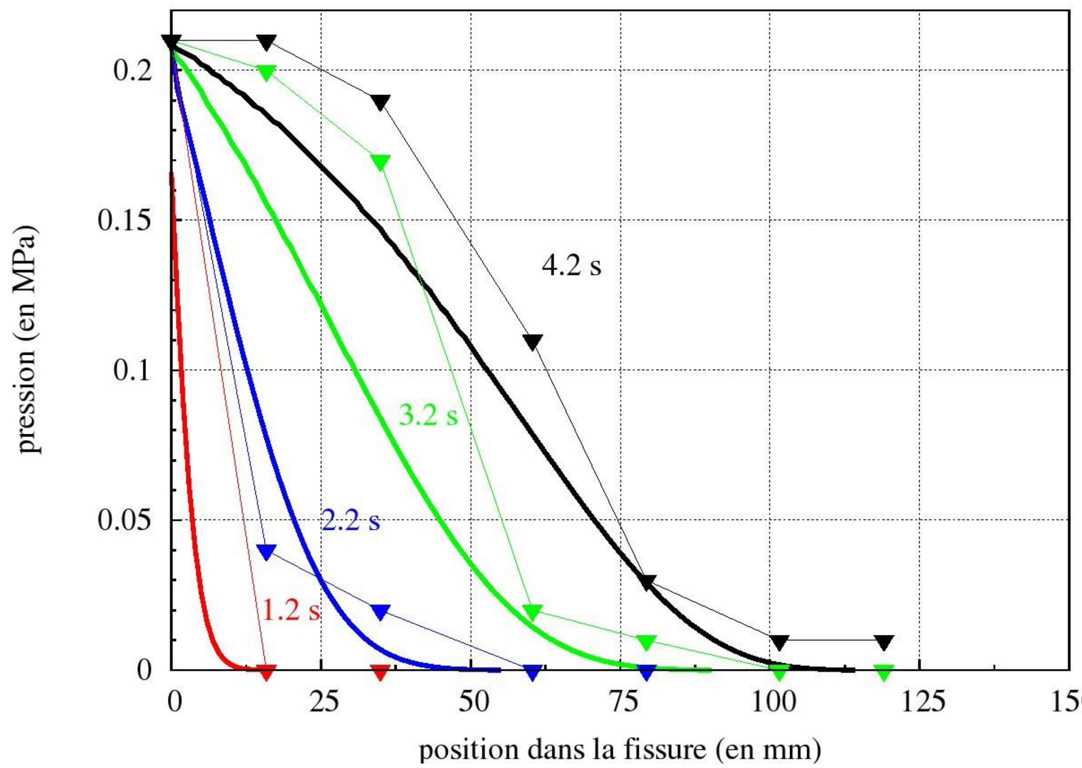


Figure 4.2-
results o

Appear 4.2-b: Profiles of pressure in crack at various times. The curves numerical are the thick curves. Experimental measurements (Slowik and Saouma) are illustrated by the full triangles

One compares the total mechanical response obtained with the experimental results.

Not	**Time (** s **)**	Fx **(** kN/mm^2 **) reference**	Fx **(** kN/mm^2 **) Aster**	**Difference (** $\%$ **)**
B'	1,0	-15,06	-14,16	6,0.2,0
B'		-5,41	-4,73	13,0
B'	3,8	-0,882	-0,834	5.4

One adds the tests of non regression following

X **(** mm **)** Y **(** mm **) Times (** s **)**	$PRE1$ **(** MPa **) reference**
0.-60.3,2	14,9.10-3
0.-60.4,2	79,6.10-3

5 Modelization C

5.1 Characteristic of the modelization

The modelization C is almost identical to the modelization A. Only the cohesive law for crack is amended: model CZM_LIN_REG is used.

Discretization in time: 24 time step of $10\mathrm{s}$.

5.2 Quantities tested and results

One carries out simply the following tests of NON-regression:

Not	Time (s)	Fx (kN/mm^2) Aster
B	100	-16,31
B	150	-6,848

X (mm)	Y (mm)	Times (s)	$PRE1$ (MPa) Aster
0.-41.190			0,1473
0.-41.240			0,1884

6 Modelization D

6.1 Characteristic of the modelization

The modelization D is almost identical to the modelization A. Only elements D_PLAN of the solid mass are modified. They are replaced by elements D_PLAN_HMS. Thus, rather than a completely impermeable medium, one considers a medium with a low permeability:

Intrinsic permeability K^{int}	$1.10-19\,m^2$

the exchanges between crack and solid mass are authorized for this modelization.

Discretization in time: 10 time step of $20\,s$.

6.2 Quantities tested and results

One carries out simply the following tests of NON-regression:

Not	**Time** (s)	Fy (kN/mm^2) **Aster**
B	100	-11,87
B	200	-2,10

X (mm)	Y (mm)	**Times** (s)	$PRE1$ (MPa) **Aster**
0.-41.140			0,0737
0.-41.200			0,1679

7 Summary of the results

the got results make it possible to validate the good performance of the elements of joints with hydro-mechanical coupling with the regularized cohesive models.

The modelizations A and B test the compatibility of the element of joint with model CZM_EXP_REG. The results are compared with experimental results. The total mechanical response of structure as well as the effect the rate loading on flow in crack are reproduced correctly numerically.

The modelization C, by test of NON-regression only, the use of model CZM_LIN_REG validates. The results are completely in conformity with what is expected.

Lastly, the modelization D makes it possible to test compatibility with the cohesive models in the presence of surface elements HM_DPQ8S far from permeable in the solid mass.